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GB 921949
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(71) Applicant
The Bendix Corporation
Executive Offices
Bendix Center
Southfield
Michigan 48076
United States of America
(72) Inventors
William B Claxton
Joseph C Cromas
(74) Agents
F J Cleveland & Company

(54) Fuel injector valve with contoured flow nozzle

(57) A transitional surface 144 connects the valve seat 126 to the metering orifice to gradually change the direction of fuel flow to avoid separation and unstable flow. The valve tip 122 narrows into a pintle 128 which extends through the metering orifice and ends in a deflection cap 130 which shapes the spray into a hollow-cone pattern. The valve tip between the pintle and closure surface 124 has a contoured surface 146 which with the nozzle bore provides an increasing flow area to a plateau value downstream of the closure surface, the flow area then smoothly decreasing from that value to where fuel exits the metering orifice.

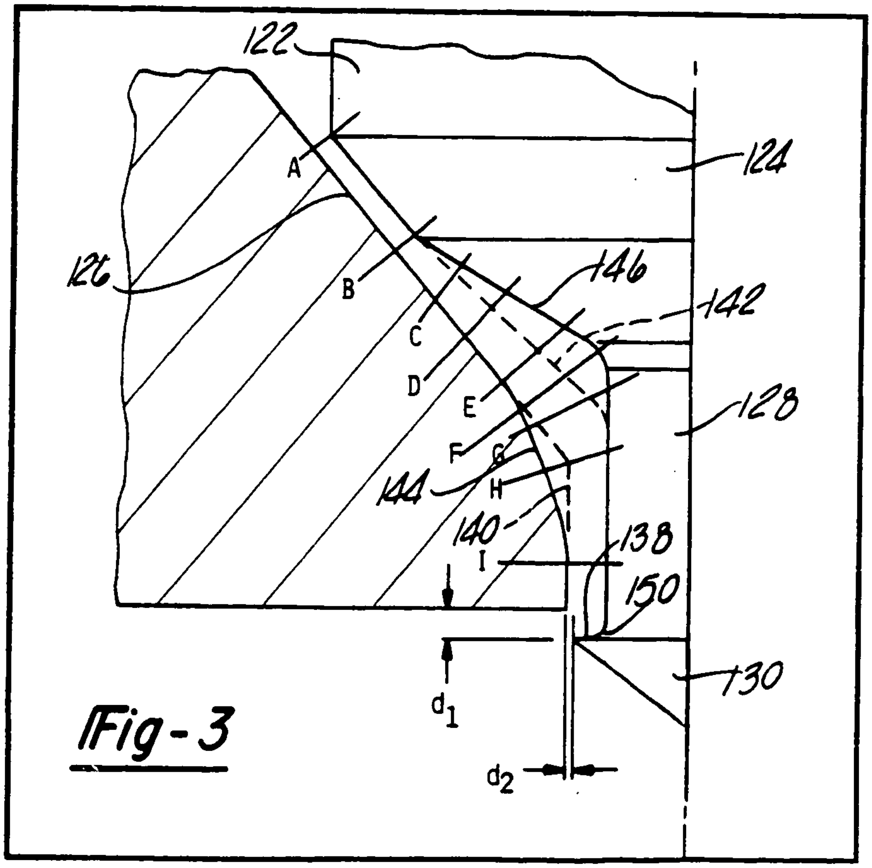

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Fig-1

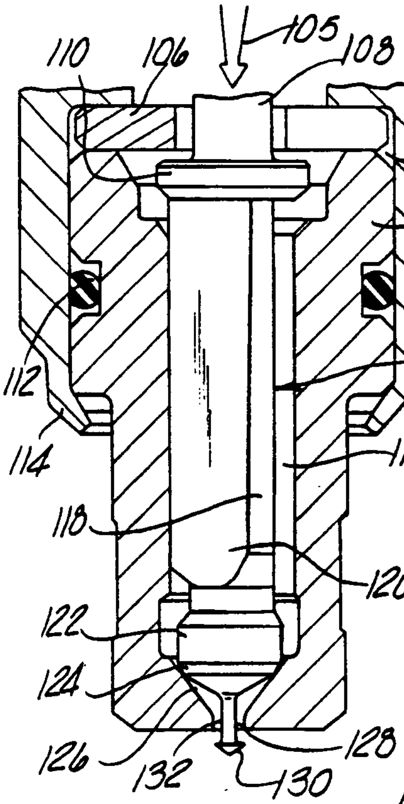
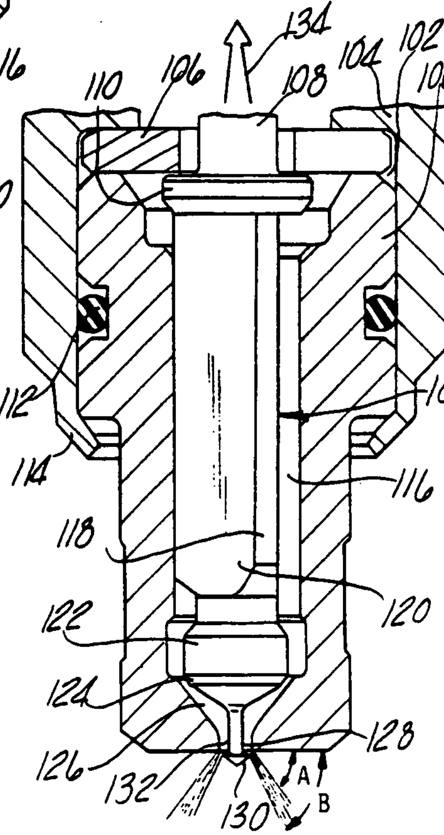


Fig-2



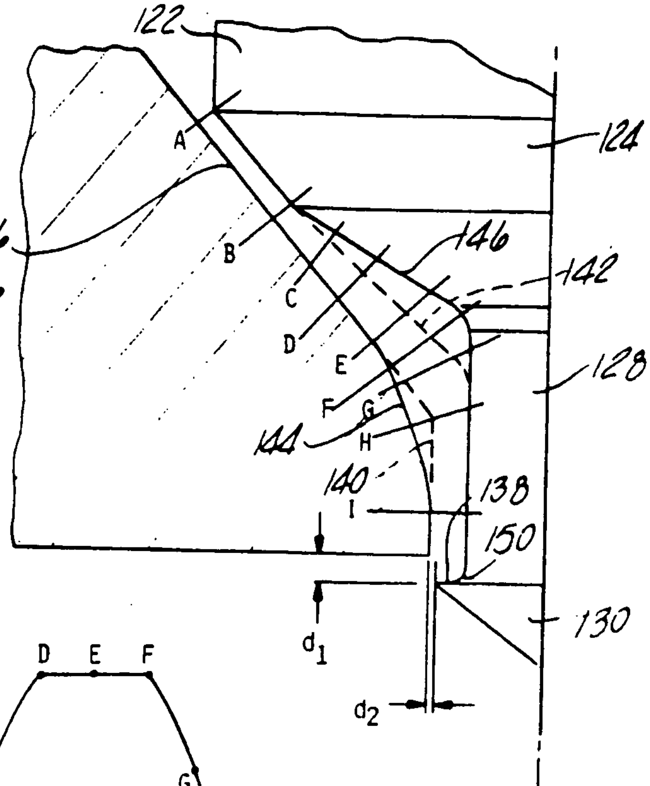

122
124
126
146
142
128
A
B
C
D
E
F
G
H
144
140
I
138
150
130
d_1
d_2

Fig-3

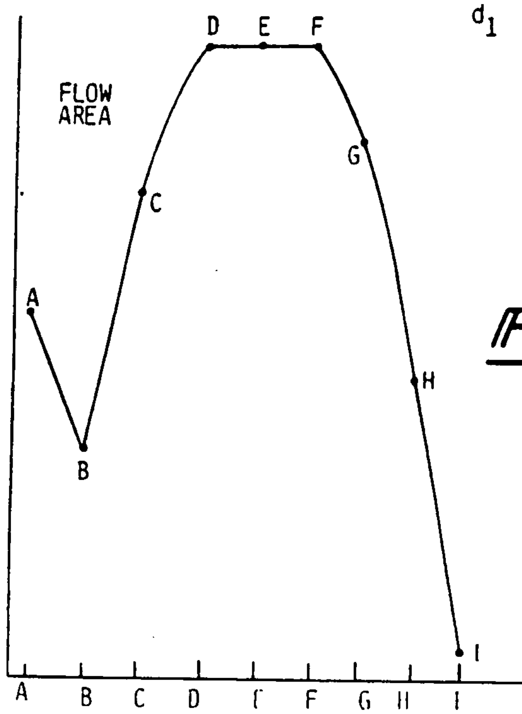

FLOW
AREA
A
B
C
D
E
F
G
H
I

Fig-4

SPECIFICATION

Injector valve with contoured valve seat and needle valve interface

The invention pertains generally to injector valves and is more particularly directed to injector valves having increased fuel flow rates.

Fuel injectors of the electromagnetic solenoid type have been commonly utilized in "multipoint" electronic fuel injection (EFI) systems in the automotive field. Such injectors are located at each cylinder of the engine and spray an atomized chrge of fuel into the intake manifold near the associated intake valve. As the intake valve opens, the atomized fuel and air from the intake manifold are drawn into the cylinder and are combusted. By controlling the duration of the operational times of the injectors with a pulse width modulated control signal from an electronic pulse width computer, the precision of fuel delivery has been greatly improved for the internal combustion engine. The fuel is metered accurately with respect to the many and varied operating parameters of the engine including manifold air pressure, rotational velocity, temperature and others. With this precision is the ability to improve fuel economy, control emissions, or increase driveability such that the conventional carburetor will probably be displaced in the future by the EFI system as the most prevelant fuel control device.

Another recent development in the fuel control field that may hasten the demise of the conventional carburetor is the "single point" EFI system which, like its counterpart the "multipoint" EFI system, depends upon the precision of electronically controlling an electromagnetic solenoid injector.

"Single point" systems usually have one injector for the delivery of fuel to a plurality of cylinders of an engine at a single injection point instead of the "multipoint" system where a one-to-one correspondence occurs. These injections points may be variably placed inside the intake manifold or the throttle bores of an air flow regulation device leading to the intake manifold. If placed in the throttle bores, these injectors may be located above or below the throttle blades for the most advantageous configuration depending on the particular injector structure. With the substitution of one injector for a plurality of injectors, the "single point" EFI system redues complexity and expense compared to many "multipoint" schemes while retaining most of the attendant EFI system advantages vis à vis the conventional carburetor.

It is desirable to inject such "single point" systems at least once p r engin ev nt (revolution) or even as fast as each intake valve opening. Since one injector replaces a plurality of injectors, sometimes as many as four for an eight-cylinder engine with a two-plane manifold, the "single point" injector generally must have a higher fuel flow rate than a corresponding "multipoint" injector. For us in higher displacement engines a higher flow rate electromagnetic solenoid injector would additionally be highly desirable whether "multipoint" or "single point".

This higher flow rate, because of the preferred single point injection timing, must b accomplished without the sacrifice of injector speed. If possible, it would be desirable for increased control that the injector speed should even be increased. If a higher flow rat is obtained at the expense of operating spe d, such an injector will not be as advantageous as if both goals are achieved. The slower the injector opening time, the less overall fuel capacity the injector will be capable of delivering in the high speed range of the engine.

Presently in the art an increased flow rate for an injection valve can be obtained by increasing the metering orifice cros-sectional area, increasing the input pressure, or a combination of both. An increase in the input fuel pressure to a single point system would, however, require the additional expense of a higher pressure fuel pump and pressure regulator combination and is, therefore, unacceptable to the basic premise of single point systems, the reduction of complexity.

However, increasing the metering orifice cross-sectional area by scaling up a conventional "multipoint" injector to a "single point" flow rate creates other problems. Initially, the opening time and thus operation capability of the injector is detrimentally affected because of the increase in the mass of the needle valve. The mass of the needle valve increases in proportion to the volume increase of the material and not linearly with the increase in flow rate. Also, the flow paths of conventional "multipoint" valves are unfavorably restricted for "single point" applications and do not have sufficient flow area therethrough to efficiently handle the increased flow rate to a larger metering orifice.

Such "multipoint" valves are illustrated in US Patents 4 007 800 issued to Hans, et al., and 3 967 597 issued to Schlagmuller, et al. They disclose the use of a needle valve in an electromagnetic injector having flats cut on four sides of the shaft. This configuration unduly restricts flow through the injector valve and increases needle mass when utilized in a high flow injector.

A US Patent 3 069 099 issued to Graham illustrates a fuel injection nozzle with a three-sided spring retainer plate. Although this configuration does not restrict fu l flow in the pressure operated injection nozzl shown it is not advantageously suitabl for precision electromagnetic solenoid injection valves where exact metering and sure closure are required.

Another problem encountered in scaling up

a conventional "multipoint" injector to a "single point" flow rate is that many injectors will not produce a stable flow at different pressures and times. At one particular pressure, for example, the static flow rate will be different some of the time and the instability unpredictable as to occurrence. This defect seems to worsen at higher flow rates and higher pressures, and is unacceptable in the "single point" flow rate and pressure range. Changes of between 5%–7% have been noted in the same injector operated at a particular pressure. The unpredictability of a flow rate from an injector will destroy the precision that the EFI systems have brought to the fuel metering art.

This unstable flow problem seems to be centered in the valve seat metering orifice interface where the cylindrical metering orifice truncates the cone of the valve seat. At higher flow reates it is believed that the fuel accelerates through the closure surface and valve seat interface and then, at unpredictable intervals, will not smoothly flow into the exit orifice. If separation occurs at the exit orifice, the fuel will not be precisely metered by the area between the outer wall of the orifice and a pintle of the valve tip. This effect is similar to the "vena contracta" phenomenon found in hydraulics where a fluid under pressure flows around a sharp corner and has an extreme change of momentum and therefore separates from the surface of an orifice.

With high flow injector valves the angle at which the valve seat intersects the cylindrical metering orifice is relatively large because of the shallow cone angle of the valve seat necesary to produce high flow rates with minimal lift from the needle valve. Reducing this intersection angle without modifying the minimal lift conical valve seat would be highly desirable. A modification to the valve seat and valve tip interface of an injector is illustrated at Fig. 4 of a US Patent 3 241 768 issued to Croft, but is for the purpose of developing a constant flow area.

Another problem that prior art injection valves with high flow rates incur is a residual fuel drop being retained on the injector or injector tip surface which effects the precision of fuel injection on subsequent openings. The residual fuel left on the injector will also cause contamination if it evaporates and can obstruct the metering orifice.

Spray pattern shaping has been attempted with "multipoint" fuel injectors and with "single point" injectors. The shaping of th pattern is important in the "single point" applications, since one injector is entraining the fuel in the air fl w at a particular time and the consequent charge is to be delivered to particular multiples of the cylinders. If the air fuel ratio precision is to be maintained and cylinder-to-cylinder distribution errors minimized, the flow pattern must be correctly designed and reproducible with every inj ction. This will minimize wall wetting and unwanted condensation of the fuel on the throttle and other surfaces.

One of the spray patterns becoming popular in "single point" injection is the hollow-cone pattern where the fuel is limited to a volume between two differently-sized cones having their apex at the injector tip. It would be advantageous to be able to reproduce such a pattern with the same injector structure ov r a wide range of operating pressures and flow rates.

Therefore, the present invention proposes a fuel injection valve having a high flow rate metering portion comprising: a valve housing having a fuel flow passage which communicates fuel from a pressurized source to a truncated conical valve seat which intersects a cylindrical metering orifice; a needle valve, reciprocal in said valve passage, including a valve tip having a closure surface which is operable to close the injection valve when brought into contact with said valve seat, said valve tip forming an interface area with said valve seat downstream of said closure surface; characterized in that a transitional surface connects said valve seat to said orifice, said transitional surface changing the direction of the fluid flow through the interface area of the valve gradually so as not to induce separation from the transitional surface.

The invention will now be described with reference to the accompanying drawings, wherein:

Figure 1 is a cross-sectional side view of an injector housing and needle valve metering combination shown in a closed position that has been constructed in accordance with the invention;

Figure 2 is a cross-sectional side view of the injector housing and needle valve combination illustrated in Fig. 1 which is shown in an op n position;

Figure 3 is an enlarged fragmentary side view in cross-section of the contoured valve seat and needle valve interface for the metering combination illustrated in Figs. 1 and 2; and

Figure 4 is a graphical representation of the flow area as a function of various positional points along the valve seat and needle valve interface illustrated in Fig. 3.

An injector valve metering portion having a "single point" fuel flow rate is illustrated in Fig. 1 in a closed position and comprises a valve housing 100 and n edle valve 107 mount d in an injector housing 104 of the valve. The construction of the injector valve other than the metering portion is n t shown as it is conventional and not pertinent to a discussion of the invention. Such portions could, for example, comprise a solenoid connected at the armature to the needle valve 107 as illustrated in the referenced Hans, et

al., the disclosure of which is incorporated by reference.

The valve housing 100 is received into a mounting chamber 102 of an injector housing 104 and is spaced exactly by a C-shaped spacer washer 106 which has its dimensions accurately controlled by machining both facial surfaces. The valve housing 100 is held securely in the mounting chamber 102 by crimping the rim 114 of the injector housing 104 over an outside shoulder of the valve housing. A suitable O-ring 112 is used to seal the interface of the mounting chamber 102 and the valve housing 100.

The valve housing 100 is provided with an essentially central valve housing bore 116. The needle valve 107 comprises a shank portion 108 which fits through C-shaped spacer 106 and then flares into a radially outgoing spacer collar 110. The spacer collar 110 adjoins a generally triangular cross-section medial section having three equilateral bearing surfaces 118 spaced equally about the valve housing bore 116 to center the needle valve 107 within the bore.

The medial section connects to a valve tip 122 having a closure surface 124 which mates with a truncated conical valve seat 126 and then narrows to finally become an elongated pintle 128. The pintle 128 extends through a cylindrical metering orifice 132 and terminates in a deflection cap 130. The bearing surfaces 118 slide within the bore 116 and are connected by relieved surfaces 120 forming fuel flow passages between them and the valve housing bore 116.

Fuel uner pressure flows into the fuel passages between the needle valve and valve housing bore 116 from a pressurized source (not shown) which feeds fuel through the opening in the spacer washer 106. The fuel is prevented from exiting an annular fuel passage formed between the cylindrical orifice 132 and the pintle 128 by means of a closure force 105 forcing the needle valve tip into sealing relationship with the valve seat 126.

In Fig. 2, fuel is metered from the valve by applying an opening force 134 lifting the needle valve 107 away from the seat and allowing fuel to pass through the closure surface 124 and valve seat interface 126 and, thereafter, the orifice 132. The needle valve 107 is lifted to where the spacer collar 110 abuts washer 106. The opening force 134 and closure force 105 can be provided by a number of means such as a solenoid, pressure, or m chanical.

When th valv is open, fuel is metered through the annular passage formed by the pintle 128 and cylindrical metering orifice 132. The flow area of the passage is precisely controlled to p rmit a desired amount per unit time at the operating pressure of the valve to be injected. The fuel flow is shaped into a hollow-cone pattern by the deflection cap 130. Th pattern has an outer cone angle A and an inner cone angle B between which substantially all of the fuel flow is contained.

Fig. 3 shows an enlarged cross-section view of the interface between the valve tip 122 and the valve seat 126. It is seen from the figure that the valve seat and metering orifice intersection, which was previously a sharp corner with a relatively large angle as indicated by dotted line 140, has been contoured into a transitional surface 144 which smoothly changes the direction from the conical face of the valve seat to the cylindrical orifice. The transitional surface 144 is shown as a curve beginning at the exit orifice and sweeping to where it becomes tangent to the valve seat surface 126.

This shape is the preferred form and can be in cross-section a circular arc or higher ordered curve, but any transitional surface which changes fuel direction gradually enough to not cause separation or cavitation in the fuel flow would be acceptable for the interface. The simplest form of the transitional surface could be a truncated conical surface beginning at the valve seat and connecting the cylindrical metering orifice. The transitional conical surface could have a greater slope than the valve seat, but less than the vertical angle of the metering orifice.

To compliment the transitional area, the valve tip 122 between the closure surface and the pintle has also been contoured from its previous shape, as shown by the dotted line at 142, to the present surface illustrated at 146. Taking cross-sectional flow area at different positions between the valve tip and the valve seat interface, it is seen in Fig. 4 that the flow area decreases from point A to point B because of the closure surface and valve seat restriction. From point B to point D it gradually increases to where a plateau level is reached at points D-F. From point F to the flow area of the annular passage, I, the flow area gradually and smoothly decreases.

The flow area between points B and points F allows the fuel to recover pressure lost going through the restricted area form A to B and slows the velocity. From point F th smooth entry of the fuel along the transitional surface into the exit orifice 132 keeps the fluid from dropping below the vapor pressure so the flow rate is stable and cavitation and separation are prevented.

The contour of the valve tip 122 and the contour of the transitional surface 144 both contribute to providing a metering valve which is stabl in fl w rate. Each can, however, be us d individually to ffect stability in inj ction valv s, but the f atures pr ferably are used in combination to create a uniting of their individual contributions.

The shaping of the hollow cone spray pattern is accomplished by the deflection cap 130 which is formed on the end of the pintle

as a con with a flat deflection edge 138 and small fillet 150 connecting to the shaft of the pintle 128. A spray axis C-C indicates the direction of fluid momentum as the fuel exits the orifice 132. Assuming a constant pressure for the injector, the hollow-cone spray pattern is generated by controlling three variables which are: the annular flow area of the fuel passage between the metering orifice and pintle, the distance between the injector housing end and the flat deflection surface 148 designated D_1, and the difference in the orifice diameter and the diameter of the base of the deflection cap designated d_2.

Generally, the smaller the distance d_1, the wider the spray pattern will be when the injector is open. Similarly, the smaller the distance d_2 is, the wider the spray pattern angle. One limitation is that the distance d_1 must be greater than that necessary to prevent restriction of the metering orifice as the delfection cap 130 is for the purpose of separating the shaping function from the metering function in the present value.

The fuel flow, as it comes out and impinges upon the deflection surface 148, changes the direction of the fluid flowing the deflection distance d_2 to form the two hollow-cone spray. The fluid deflected substantially perpendicular to the spray axis C–C by the deflection surface 138 will cause movement away from spray axis in the horizontal direction by a component related to the amount of flow and the amount of flow deflected. The larger the amount of flow deflected to that of the entire flow, the smaller the angles of the hollow-cone pattern.

As an example, a hollow-cone spray patter with an inner cone angle B of 60° and an outer cone angle A of 30° can be formed by an injector having a metering orifice of .84mm diameter and a pintle diameter of .56mm. The distance d_1 for this injector would be approximately .41mm and the distance d_2 would be .025mm, or having a deflection cap with an outside base diameter of .81mm. Such an injector would be designated to run at approximately 2.8 kg/cm² and have a single float point flow rate of about 20 kg/hr.

A lower pressure injector running at approximately 1 kg/cm² and the same flow rate with an inner cone angle B of 30° and an outer cone angle A of 10° can be advantageously manufactured by having a metering orifice of 1.12 mm with a pintle outside diameter of .64mm. This valve would have distance d_1 of .61mm. For this spray angle, a difference of .050mm, or distance d_2, between th outside diameter of the base of the deflection cap and the metering orifice is desired, or where th bas of the deflection cap equals 1.07mm in diameter.

While the preferred embodiments of the invention have been shown, it will be obvious to those skill d in the art that modifications and changes may be made to the disclosed systems without departing from the spirit and scope of the invention as defined by the appended claims.

CLAIMS

1. A fuel injection valve having a high flow rate metering portion comprising: a valve housing having a fuel flow passage which communicates fuel from a pressurized sourc to a truncated conical valve seat which int rsects a cylindrical metering orifice; a needle valve, reciprocal in said valve passage, including a valve tip having a closure surface which is operable to close the injection valve when brought into contact with said valve seat, said valve tip forming an interface area with said valve seat downstream of said closure surface, characterized in that a transitional surface connects said valve seat to said orifice, said transitional surface changing the direction of the fluid flow through the interface area of the valve gradually so as not to induce separation from the transitional surface.

2. A fuel injection valve with a metering portion according to claim 1, characterized in that said transitional surface is formed as a truncated conical surface with a greater conical slope than said valve seat.

3. A fuel injection valve with a metering portion according to claim 2, characterized in that said transitional surface is formed as a curvature connecting said valve seat and said metering orifice.

4. A fuel injection valve with a metering portion according to claim 3, characterized in that said radius of curvature is formed by a circular radius being extended from the inlet end of said metering orifice to where it is tangent to said conical valve seat.

5. A fuel injection valve with a metering portion according to anyone of claims 1 to 4, characterized in that said valve tip narrows into a pintle which extends through said metering orifice, said valve tip being contoured between said closure surface and said pintle such that the flow area of the valve tip and valve seat interface increases to a plateau value and subsequently decreases smoothly to where the fuel exits the metering orifice.

6. A fuel injection valve with a metering portion according to claim 5, characterized in that said valve tip terminates in a deflection cap having a deflection surface ending in an edge substantially perpendicular to the injector spray axis.

7. A fuel injection valve with a metering portion according to claim 6, characterized in that said deflection surface controllably f rms a hollow-cone spray pattern with an inner cone angle and outer cone angle by varying the distance of the d flection surface with respect to the end of the exit orifice.

8. A fuel injection valve with a met ring

porti n according to claim 7, characterized in that said inner and outer cone angles are controllably formed by varying the distance between the diameter of the base of said deflection surface and the diameter of said metering orifice.

9. A fuel injection valve with a metering portion according to claim 8, characterized in that said inner and outer cone angles are controllably formed by varying the flow area of the annular fuel passage formed between said pintle and said metering orifice.

10. A fuel injection valve substantially as described and as shown in the accompanying drawings.

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